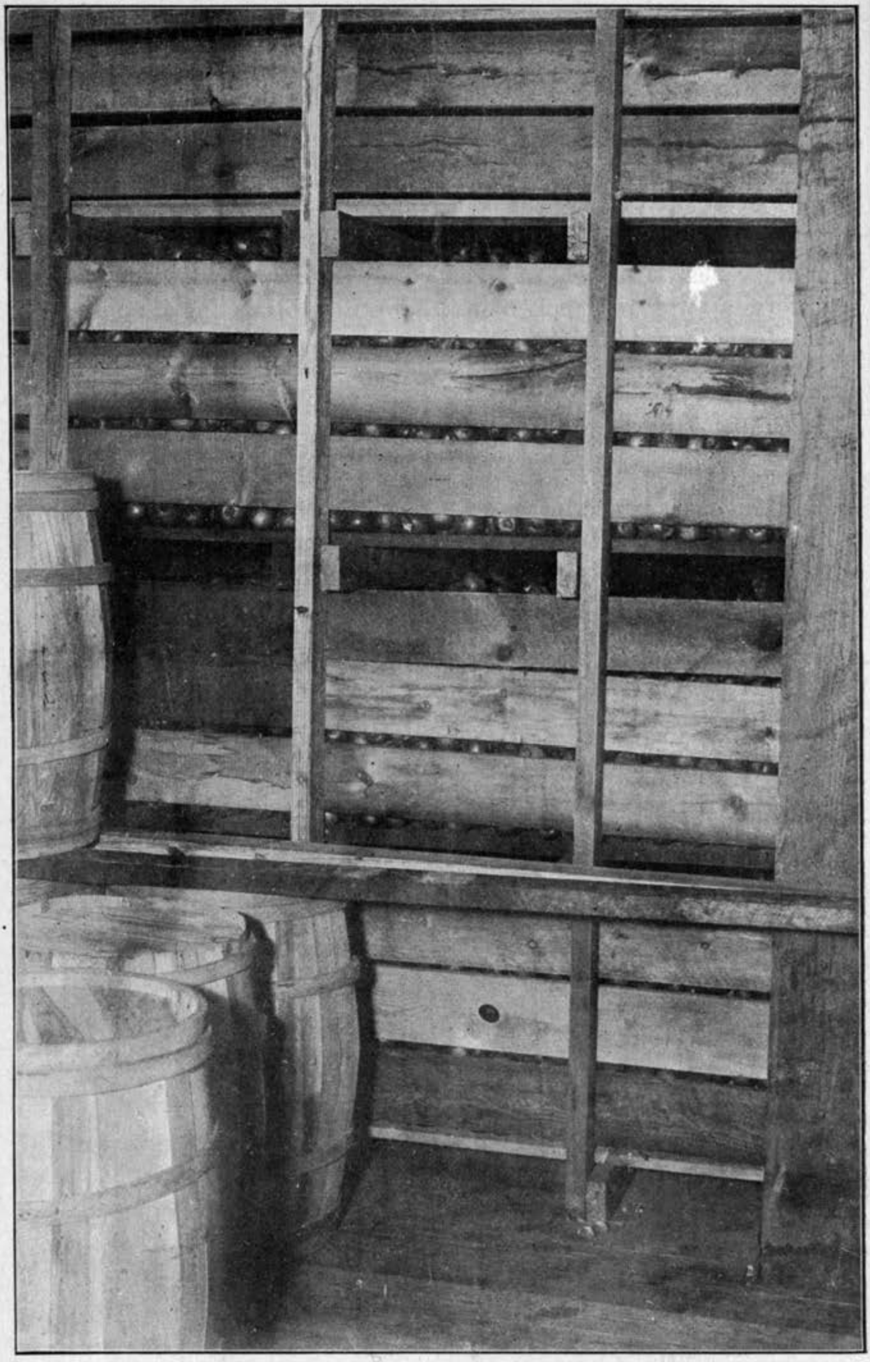

FRUIT BINS IN NEOGA HOUSE.

"'Twere easier to teach twenty men what were good to do than to persuade one man to do."—*Modern Shakespere.*

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METHODS OF MAINTAINING THE PRODUCTIVE CAPACITY OF ILLINOIS SOILS.*

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If the greatest study of mankind is Man, the next greatest study is the soil; for, upon the soil depends the preservation of Man.

If it is true that American agriculture is the fundamental support of the American Nation, it is equally true that soil fertility is the absolute support of American Agriculture.

If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two have been grown before is a public curse.

*An address read before the Illinois State Farmers' Institute at Bloomington, February 25, 1903, now published as an Experiment Station Circular for general distribution among the farmers of Illinois, because it is believed that this information will be of value to very many Illinois farmers and land owners. More complete data regarding the exact composition and location of all soils which have been sampled and analyzed will be published in bulletin form for free distribution within a few months. The bulletin will contain a general survey soil map of the State printed in colors, which will be much more distinct, than the map printed in this circular.

The fertility of Illinois soils ought not and need not be reduced; Illinois land ought never to be reduced below its original productive capacity.

The only system of maintaining soil fertility which I can advocate and which can ever safely be adopted as a permanent system must be a system which can be applied to all of the soils of this State,—not to a few farms only, or for a few years only, but to all the soils of Illinois, and for all time,—yes, even more than that,—it should be a system which can be applied to the soils of adjoining states,—to Indiana and Ohio,—to Wisconsin and Iowa,—in short, to the soils of America.

How shall the fertility of the soil be maintained? We hear two very common answers to this question:

The grain farmer says we must grow clover.

The live stock farmer says we must put the manure back on the land.

But neither of these answers really answers the question.

Clover will not maintain the fertility of the soil, and, if all of the crops which are grown on the farm are fed on the farm and the manure all returned to the land, it will not maintain the fertility of the soil, not even if clover is also grown. The only way by which the live stock farmer can maintain the fertility of his soil by the use of manure is to feed not only his own crops but his neighbors' crops also, and then put all the manure upon his own land.

This answers the question for a few farmers who are also extensive cattle feeders, but it does not answer the question for Illinois; it does not answer the question for America;—we cannot all feed our own crops and our neighbors' crops also.

How then shall we maintain the fertility of Illinois soil?

There is but one answer to this question, and this answer would have saved the fertility of all the soils which have been ruined in past ages. It would have saved the soils of Palestine, a land which once flowed with milk and honey but is now a barren waste. It would have saved the soils of Greece, and of Italy, of Northern Europe and of Eastern United States, and it is the only answer which will save the soils of Illinois,—and this is the answer:

Preserve good physical conditions and then put back upon the land all of the fertility which is taken off,—not some of it, not most of it, but all of it: and not only that which is removed by cropping but also that removed by the blowing, washing, or leaching of the soil.

The whole subject of plant food is a simple one. About 95 per cent. of most agricultural plants consist of the three elements carbon, hydrogen, and oxygen, which are obtained from air and water.

Only seven essential elements are furnished by the soil, and four of these, calcium, magnesium, iron and sulphur, are used by plants in such small amounts and are contained in all ordinary soils, in such large amounts that they are practically never exhausted from the soil.

The productive capacity of practically all soils in good physical condition is measured by the available supply of the three elements, nitrogen, phosphorus, and potassium. These are the elements which are present in nearly all soils in comparatively small amounts and yet are absolutely required by all agricultural plants, and in very considerable quantities.

How shall the fertility of the soil be maintained? By maintaining the supply of nitrogen, phosphorus, and potassium, and preserving good physical conditions. How shall the productive capacity of a soil be increased? By increasing the supply of that element which is most deficient in the soil.

The live stock farmer understands the value of a balanced ration in stock feeding. Let us also bear in mind that plants are living things, and that balanced rations are of even greater importance to them than to animals. Timothy hay and corn-and-cob meal have some place in animal feeding, but they do not make the best possible balanced ration for young cattle or milk cows, nor could you make a balanced ration by adding to them excelsior straw and sawdust meal. Likewise a plant which is starving for phosphorus is not benefited by plowing under a crop of green rye or even by feeding it more nitrogen or potassium; indeed such treatment would tend to still further unbalance the soil and might even produce an injurious effect upon the plant, as appears to have been the case to a slight extent in some experiments (see Table 7, (a) 8 and (b) 7).

Special Note. The tables given in this circular have been prepared with very great care. They may not be very entertaining to the careless reader; but to any one who is willing to take some time to study them, to compare one with another,—in short to do some real thinking along these lines,—to such a one these tables contain a large amount of very useful and valuable information bearing directly upon the business of farming and the science of agriculture.

By referring to Table 1, which is self explanatory, one may see some of the absolute requirements of different kinds of farm produce for the different elements of plant food.

TABLE I. FERTILITY IN FARM PRODUCE.
(Approximate maximum yields per acre.)

Produce.		Pounds.			Value.			
Kind.	Amount.	Nitrogen.	Phosphorus.	Potassium.	Nitrogen.	Phosphorus.	Potassium.	Total Value.
Corn, grain...	100 bu.	100	17	19	$15.00	$ 2.04	$ 1.14	$18.18
Corn stover..	3 T.	48	6	52	7.20	.72	3.12	11.04
Corn crop ...		148	23	71	22.20	2.76	4.26	29.22
Oats, grain ..	75 bu.	45	7	9	6.75	.84	.54	8.13
Oat straw....	2 T.	24	4	40	3.60	.48	2.40	6.48
Oat crop.....		69	11	49	10.35	1.32	2.94	14.61
Wheat, grain.	40 bu.	46	6	11	6.90	.72	.66	8.28
Wheat straw.	2 T.	19	4	34	2.85	.48	2.04	5.37
Wheat crop..		65	10	45	9.75	1.20	2.70	13.65
Timothy	2 T.	48	6	47	7.20	.72	2.82	10.74
Clover	3 T.	120	15	90	18.00	1.80	5.40	25.20
Cowpea hay.	3 T.	140	14	95	21.00	1.68	5.70	28.38
Alfalfa	8 T.	400	36	192	60.00	4.32	11.52	75.84
Apples......	600 bu.	47	2	57	7.05	.24	3.42	10.71
Leaves	4 T.	59	7	47	8.85	.84	2.82	12.51
Wood growth	$\frac{1}{50}$ tree	6	2	5	.90	.24	.30	1.44
Total crop...		112	11	109	16.80	1.32	6.54	24.66
Potatoes	300 bu.	63	13	90	9.45	1.56	5.40	16.41
Sugar beets..	20 T.	100	18	157	15.00	2.16	9.42	26.58
Fat cattle ...	1,000 lb.	25	7	1	3.75	.84	.06	4.65
Fat hogs	1,000 lb.	18	3	1	2.70	.36	.06	3.12
Milk	10,000 lb.	57	7	12	8.55	.84	.72	10.11
Butter.......	500 lb.	1	0.2	0.1	.15	.02	.01	.18

The table is arranged to show the number of pounds of each element required by different kinds of produce on the basis of approximate maximum yields per acre. Of course, proportionate amounts would be required for any other yields which one may wish to consider, but I think we should be most interested in knowing the amount of plant food required to make maximum yields.

The total value of the elements is computed on the basis of the present market values,—

Nitrogen, 15 cents a pound.
Phosphorus, 12 cents a pound.
Potassium, 6 cents a pound.

It should be borne in mind that the principal value given is for the element nitrogen, which, however, the farmer does not need to purchase. The total quantity of phosphorus or potassium required by crops could be supplied at very moderate cost.

I offer the following simple rules for improving soils and feeding plants:

Rule 1—If the soil is acid, or sour, apply lime to it to make it sweet.

Rule 2—If the soil is poor in nitrogen only, grow clover or some other legume which has the power to secure nitrogen from the air.

Rule 3—If the soil is poor in phosphorus only, apply bone meal or some other form of phosphorus.

Rule 4—If the soil is poor in potassium only, apply potassium chlorid or some other form of potassium.

Rule 5—Always save and use all the barnyard manure you have, and also all you can economically obtain from others, and make liberal use of green manures when necessary to maintain the supply of organic matter in the soil.

In connection with these five rules for improving soils and feeding plants, I offer the following suggestions :

1. Regarding Lime.

Lime is the only material which we can use for correcting the acidity of soils. It may be used in several forms : (1) fresh burned quicklime, which is calcium oxid, a compound of the elements calcium and oxygen; (2) fresh slacked lime, which is calcium hydroxid, a compound of quicklime and water; (3) old air-slacked lime, which is calcium carbonate, a compound of quicklime and the carbon dioxid from the air; (4) fine ground limestone, which also is calcium carbonate, exactly the same as old air slacked lime; (5) marl, which also contains calcium carbonate, the same as limestone.

Any of these five different forms of lime may be used to correct the sourness, or acidity, of soils, and after the acidity of a soil is once corrected, probably half a ton of lime per acre once in five years will be enough to keep the soil sweet. From the knowledge which we have thus far obtained, we believe that old air-slacked lime, fine ground limestone, and marl are the most economical forms of lime to use.

Fresh burned lime (quicklime) can be delivered in bulk at almost any point in Illinois for $5.00 a ton in carload lots.

Slacked lime can be bought from J. B. Speed & Company, Louisville, Kentucky, in 100-pound bags, on board cars at their works at Milltown, Indiana, for $2.50 a ton, if the empty bags are returned in good condition. The freight rate is $1.00 to $1.20 per ton in carload lots to such points as Centralia, Olney, Salem, and Odin.

Old air-slacked refuse lime can frequently be found in large quantities lying about the lime kilns in different parts of the State. It often contains some cinders and some lumps of stone which could be easily screened out. I believe lime companies could screen this material and place it on the cars for about 50 cents a ton, provided they could sell large quantities of it.

Fine ground limestone is now offered for sale by the Crystal Carbonate Lime Company, of Elsberry, Missouri, for $1 per ton in bulk loaded on the cars at Elsberry. The special freight rate on this material to some points in Central Illinois (Springfield and Peoria) is $0.80 to $1.00 a ton, in car load lots. The Mitchell Lime Company, Mitchell, Indiana, have quoted fine ground limestone delivered at Odin, Centralia, Mt. Vernon, etc., for $2.70 per ton in bulk in car load lots. A plant for grinding limestone to a fine powder can be erected at a cost of less than $8,000; and, with the abundance of excellent limestone in different parts of Illinois, there is no reason why we should not have fine ground limestone delivered at any point in Illinois at very moderate cost.

Although our absolute knowledge upon the subject is still meager, my opinion is that fresh burned lime or fresh slacked lime will not prove to be the best form of limes to use, partly because they evidently have a tendency to attack and destroy the organic matter of the soil or "burn the land", as some say, and partly because the natural products (as ground limestone) are less disagreeable to handle. In power to neutralize acids, 56 pounds of quicklime would be equivalent to 74 pounds of fresh slacked lime and to 100 pounds of ground limestone, provided that all materials were perfectly dry and pure, and further provided that the full force were exerted in neutralizing soil acids, which is certainly the case with ground limestone, while with fresh burned lime (quicklime) and fresh slacked lime the force or power is evidently partly used up in destroying organic matter, although the destruction of organic matter cannot be very large. As stated before, any of these forms of lime may well be used, but with quicklime at $5.00 a ton, fresh slacked lime at $3.70 a ton, and lime carbonate (ground limestone) at $2.80 at ton, I would prefer to use the ground limestone.

As a rule, raw products are cheaper than manfactured goods, and let us bear in mind that the lime naturally in the soil is in the form of ground limestone; and I may add that the phosphates and potash salts naturally in the soil are also in the form of pulverized or finely divided rock, more or less decomposed by natural agencies.

2. Regarding Nitrogen.

If any question pertaining to the science and practice of agriculture is settled, it is this,—that the atmosphere is the most economical source of nitrogen for all general farming; but let me ask you to bear in mind: (1) that neither clover nor alfalfa nor cow peas nor soy beans nor any other leguminous crop is able of itself to secure nitrogen from the air, but that each different legume must be provided with the particular species of bacteria which has the power to live upon its roots and to gather atmospheric nitrogen for its use: (2) that these nitrogen-gathering bacteria will not live in strongly acid soils and will not properly develop in any soil which needs lime: (3) that leguminous crops do not live upon nitrogen alone, but that they must have both phosphorus and potassium, although deep rooting legumes, like alfalfa, when once well started are usually able to obtain large supplies of those elements from the lower subsoil.

3. Regarding Phosphorus.

So far as I have discovered, in all other things Illinois farmers are intelligent, reasonable, progressive, consistent, and unprejudiced; but, regarding the use and value of that element of fertility which limits the productive capacity of a large proportion of Illinois soils, I am compelled to say that Illinois farmers, as a rule, are inconsistent, if not actually prejudiced.

Phosphorus is the one element of fertility above all others which has a high absolute and permanent value to Illinois farmers.

Nitrogen is free as air and potassium is abundant in nearly all of the soils of the State and both nitrogen and potassium remain in the straw and corn stalks and in the farm manures to a considerable extent. Phosphorus, on the contrary, is present in nearly all soils in limited amounts and it is being continually removed from the land both by grain farming and live stock farming, although two or three times faster by grain farming than by the live stock system of farming. The sin of the live stock farmer is the same as that of the grain farmer; the only difference is in degree. As a rule, the sins of the grain farmer will fall upon his own head, while the sins of the live stock farmer will fall more heavily upon his children.

The phosphorus which is taken from the soil by plants is largely stored in the seed or grain and thus the grain farmer sells it from the farm. If the grain is fed to animals, from one-third to one-half of the phosphorus is stored in the animals' bones and thus the live stock farmer sells it from the farm.

I have talked with many Illinois farmers about using bone meal on their soil and not infrequently some one looks at me as though I were a traitor to the cause of better agriculture in Illinois and he says, "Then you advocate the use of commercial fertilizers."

Is it not a shame to call bone meal a commercial fertilizer? Pure bone meal is not a commercial fertilizer in the ordinary sense; it is not a manufactured article; it is a farm product, and any method of reasoning which justifies the use of farm yard manures will justify the use of bone meal upon the land from which it came.

In this connection let me say that I do not advocate the use of highly manufactured commercial fertilizers upon Illinois soils, not even the indiscriminate use of mixed fertilizers; and from what information we now have I strongly advise against the use of any acidulated fertilizers, such as "dissolved" bone, acidulated bone meal, acid phosphates, superphosphates, or any other fertilizers which have been treated with sulphuric acid, or oil of vitrol. Of course, I am aware that these acidulated phosphates are readily available and may give quick returns and some profit, but I am also convinced that they are too expensive and that, as a rule, their continued use works no permanent good to the land. The opinion held by many eastern farmers that they ultimately injure or "burn" the land is evidently not without some foundation; and I fear that the acid soils of Illinois would not be permanently benefited by the use of acid phosphates. On the other hand, when acid phosphates are used with lime or applied to soils which naturally contain an excess of lime, the soluble phosphate reacts with the lime and quickly reverts to a form which is no more readily available than some non-acidulated phosphates.

I believe there are only three forms of phosphorus which should be considered for use on Illinois soils:

1. Fine ground bone meal.
2. Fine ground rock phosphate.
3. Fine ground slag phosphate.

I prefer steamed bone meal to raw bone meal, partly because the steamed bone meal acts more quickly in the soil, and partly because, for its phosphorus content, the steamed bone is cheaper. The nitrogen contained in the raw bones is charged for at about 15 cents a pound, but by steaming the bones the nitrogen is largely removed in the form of glue, and the steamed bone is then sold almost wholly for its phosphorus content. Even steamed bone meal still contains some nitrogen, which is of course no objection to its use although it adds but very little to its real value for the ordinary farmer, as he can obtain nitrogen from the atmosphere at very small cost, by proper use of leguminous crops, if his soil is in suitable condition. Bone meal should be bought only on the basis of its phosphorus content.

The best steamed bone meal contains about 12 to per 13 cent. of phosphorus, which at 12 cents a pound would give it a value of $30 per ton. It can usually be bought from fertilizer dealers in Chicago (as Nelson Morris & Company, Armour Fertilizer Works, or Swift & Company) for about $28 a ton, in 200-pound bags, delivered at points in Illinois. Somewhat poorer grades are sold at lower prices. (Phosphorus is commonly sold under the name of phosphoric acid, by which is meant a compound of phosphorus and oxygen containing 43⅔ per cent. of the element phosphorus. Consequently, if phosphorus is worth 12 cents a pound, this compound, "phosphoric acid" is worth about 5 cents a pound.)

Fine ground rock phosphate, containing 12 to 13 per cent, of phosphorus, can be bought from Robin Jones of Nashville, Tennessee, (and probably from other dealers) for $4 a ton in bulk (or $4.40 in bags), on board the cars at the mines, and the freight rate now in effect from the mines in Tennessee to Chicago is $3 22 per ton of 2000 pounds. Thus, this material can be delivered in Illinois for $7 or $8 a ton. As it is just as rich in phosphorus as good steamed bone meal, the phosphorus in the rock would cost only 3 cents a pound. In other words, the 17 pounds of phosphorus contained in 100 bushels of corn would cost $2.04 if bought in the form of bone meal, while it would cost only 51 cents if bought in rock phosphate. In bone meal the phosphorus for a bushel of corn costs 2 cents; in rock phosphate it costs ½ cent. In either case the cost is small as compared with the total cost of the corn crop. If we buy the land and plow the ground, prepare the seed bed, plant the seed, cultivate the corn, and harvest the crop, why not give some consideration to feeding the plant, especially when the cost of all the farm operations in growing the corn crop is just the same whether we grow 37 bushels, or a hundred bushels, to the acre.

It seems very probable that the phosphorus in the rock phosphate will be less readily available than in the bone meal, but, if four or five times as much rock phosphate is used, its effect will probably be observed just as soon and it will certainly be much more lasting than the effect of the bone meal.

Slag phosphate is simply the finely ground slag produced in the manufacture of steel from iron made from ores which are rich in phosphorus. The best slag contains about 8 per cent. of phosphorus and it also contains some excess of lime which is added to the converter in which the iron is converted into steel. The amount of lime which the slag phosphate contains would probably add somewhat to its value for use on Illinois soils, many of which are already in need of lime; but at the present time no slag phosphate is produced in this part of the country, the iron ores used by the Illinois Steel Works being very poor in phosphorus. Considerable quantities of slag phosphate are produced in Pennsylvania, and are being used on the soils of the Eastern States. Slag phosphate can be obtained from Jacob Reese, Pottstown, Pennsylvania.

The phosphorus fertilizers which are commonly used in the United States are the most expensive kinds obtainable. They are highly manufactured articles. This is largely due to the fact that most farmers who use fertilizers demand a kind which can be applied when the seed is sown and then be completely available for use of that crop. They may spend a dollar to save ten cents' worth of time and interest, and at the end of the year leave the land in worse condition than they found it at the beginning. Of course, the manufacturer caters to this demand. For example, he takes one ton of rock phosphate worth $4, adds to it one ton of sulfuric acid (oil of vitrol) worth $12, and he then has two tons of an acid phosphate which sells in Illinois for about $18 a ton, or $36 for the two tons of product containing no more phosphorus than is contained in one ton of the original rock phosphate which could be delivered in Illinois for about $7, or for one-fifth of the cost of the manufactured product. Of course the manufacturer must have pay for handling the sulfuric acid, for mixing it with the rock, and for bags and freight for two tons of material which he is compelled to handle.

If it is true that the farmers of the eastern and southern states can use this high-priced acid phosphate in a hand-to-mouth way, buying more or less nitrogen and potassium at the same time, and still make some profit on lands which are poorer than Illinois soils in all other elements than phosphorus, it is certainly highly probable that Illinois farmers could profitably supplement their farm manure and clover fertilizers with steamed bone meal, or natural rock phosphate, neither of which can ever injure the soil in the least; and thus by applying large amounts of low-priced phosphorus fertilizers they would cause the productive capacity of the land to gradually increase instead of allowing it to slowly decrease, as under the present system of farming.

4. Regarding Potassium.

If a soil is rich in all elements of plant food except potassium, that element can be supplied with marked profit, either in the form of potassium chlorid (commonly but incorrectly called "muriate of potash") or potassium sulfate or kainit. The potassium chlorid contains about 42 per cent. of the element potassium, and sells at about $50 a ton in Chicago. The potassium sulfate contains about 40 per cent. of potassium, but it sells for about $55 a ton, the sulfate being somewhat more agreeable to handle than the chlorid and it is also preferred for use with some particular crops not grown in this State. Kainit is a crude potash mineral containing about 10 per cent. of potassium. It sells for about $16 a ton. It will be seen that potassium chlorid is somewhat the cheapest form of the element potassium, although kainit gives very good results and is very largely used where potassium is the only element required. (Potassium is usually sold under the name of potash, a compound of potassium and oxygen containing 83 per cent. of the element potassium. If the element is worth 6 cents a pound, the compound called potash is worth about 5 cents.)

5. Regarding Farm Manure.

Manure is a complete fertilizer; that is, it contains some of all of the elements of fertility; but manure is not a well balanced fertilizer, because it contains too little phosphorus, much of the phosphorus being retained in the bones of the animals, while the bedding or litter is usually poor in that element (see Table 2 for phosphorus content of straw and corn stalks). Manure does contain a small amount of phosphorus, but it is much more valuable for the potassium and nitrogen which it contains and also for the humus, or organic matter, which it adds to the soil, and sometimes for the soil bacteria which it also supplies to the land. Farm manure always has been, and without doubt always will be, one of the principal materials used in maintaining the fertility of Illinois soils; but, as a rule, it is not well balanced and there are some things which it cannot do. For example, it cannot correct an acid soil and it cannot maintain the supply of phosphorus in the soil unless much more manure is used on a given farm than can be made from the crops produced on that farm alone. (At the full market price for phosphorus, 12 cents a pound, a ton of fresh manure is worth about 24 cents for its phosphorus content.) As a very general rule, farm manure should not be replaced in maintaining or increasing the fertility of the soil, but if necessary it should be supplemented,—by lime and by some form of phosphorus, as bone meal or rock phosphate. On some few soils, however, such as peaty lands, the use of farm manure may well be entirely replaced by the use of potassium fertilizers, as will be shown later. (See Table 6—peaty swamp soil.) Peaty soils contain an abundance of both nitrogen and humus, the two constituents for which manure is most valued. Manure is most useful on soils which are deficient in humus, upon the supply of which the soil is largely dependent for its capacity to absorb and retain moisture and thus to resist drouth. As a source of humus, however, manure may well be supplemented, and if necessary, entirely replaced by any other organic matter, including green manure crops, although, if heavy crops of green manures are added to the soil, care must be taken that the soil contains sufficient lime to keep it sweet, as

TABLE 2. FERTILITY IN MANURE, ROUGH FEEDS, AND FERTILIZERS.

Name of material.	Pounds per ton.			Value per ton.			
	Nitrogen.	Phosphorus.	Potassium.	Nitrogen.	Phosphorus.	Potassium.	Total value.
Fresh farm manure	10	2	10	$ 1.50	$ .24	$ .60	$ 2.34
Corn stover........	16	2	17	2.40	.24	1.02	3.66
Oat straw..........	12	2	20	1.80	.24	1.20	3.26
Wheat straw.......	10	2	17	1.50	.24	1.02	2.76
Clover hay.........	40	5	30	6.00	.60	1.80	8.40
Cow pea hay.......	43	5	33	6.45	.60	1.98	9.03
Alfalfa hay.........	50	4	24	7.50	.48	1.44	9.42
Dried blood........	280			42.00			42.00
Sodium nitrate.....	310			46.50			46.50
Ammonium sulfate.	400			60.00			60.00
Raw bone meal.....	80	180		12.00	21.60		33.60
Steamed bone meal	20	250		3.00	30.00		33.00
Acidulat'dbone meal	40	140		6.00	16.80		22.80
Slag phosphate.....		160			19.20		19.20
Rock phosphate....		250			30.?		30.?
Acid phosphate.....		125			15.00		15.00
Potassium chlorid... (muriate of potash.)			840			50.40	50.40
Potassium sulfate... (sulphate of potash.)			800			48.00	48.00
Kainit			200			12.00	12.00
Wood ashes[1]........ (unbleached)		10	100		1.20	6.00	7.20

1. Wood ashes also contain about 1000 pounds of lime carbonate per ton.

considerable acidity is produced by the decomposition of the fresh organic matter.

Table 2 gives the average quantities in pounds per ton of the different valuable elements of plant food contained in ordinary manure, in litter and rough feeds, and in some fertilizers.

It will be observed that a ton of the best steamed bone meal or a ton of the richest rock phosphate contains about 125 times as much phosphorus as a ton of fresh manure; while a ton of potassium chlorid, 80 per cent. pure, as commonly sold on the market, under the name of "muriate of potash", contains about 84 times as much potassium as a ton of manure.

By referring to Table 1 and Table 2, it will be seen that about two tons of fresh manure would furnish as much potassium as 100 bushels of corn would remove from the soil, while the 100 bushels of corn would remove 4 times as much phosphorus and 5 times as much nitrogen as the two tons of manure would furnish. Thus for our common system of harvesting corn (leaving the stalks in the field) we have the problem in pounds of fertility as follows:

POUNDS OF FERTILITY.

	Nitrogen.	Phosphorus.	Potassium.
100 bushels corn contain	100	17	19
2 tons farm manure contain....	20	4	20
Difference........	80	13	
100 pounds bone meal to balance......................		13	
Balance still due..	80		

Of course the balance of nitrogen can be most economically supplied by the growing of leguminous crops, but unless one has unlimited quantities of manure he will find it a wise and profitable practice on soils needing phosphorus to balance his ration for corn by applying bone meal or rock phosphate with his manure and clover fertilizer. The Ohio Experiment Station has shown that the value of manure is increased 30 per cent. by adding to it a small amount of fine ground rock phosphate, even after paying the cost of the rock phosphate; and this value has been measured in actual increase in crop yields.

The rock phosphate or bone meal can be mixed with the manure as it is made, using about one pound for each animal per day or it can be spread on the field with the manure, preferably perhaps with a manure spreader; or it can be sowed by itself with an end gate seeder.

As already stated the fertility of the soil can be maintained or even increased by the use of farm manures alone, but much more manure will be required than can be produced from the crops grown on the farm. In the famous experiments which have been conducted for more than sixty years at Rothamsted, England, the average yield of wheat has been maintained, by use of farm manures alone, at more than thirty bushels of wheat per acre. But how has this been done? *By applying 14 tons per acre of good barn yard manure every year.* But who can make 14 tons of good manure from the refuse left from a 30-bushel crop of wheat?

It is an easy thing, and usually it is a popular thing, to say that farm manure and legumes are the only fertilizers you need to use, and that the purchase of any other fertilizer is a waste of money; but I would indeed be a traitor to Illinois Agriculture if I allowed myself to spread abroad this popular opinion.

I know and you know, that even the average Illinois live stock farmer not only does not and cannot apply 14 tons of manure per acre every year, but as a rule he cannot make an application of eight tons of manure per acre more than once in four years; while as a matter of fact what he actually does do is usually to scatter the manure over a few thin places near the barn and give the remainder of his farm an occasional "rest" by pasturing.

Whenever you can make two minus one equal two, then you can maintain the fertility of the soil without putting back as much plant food as is taken off. The merchant buys and sells and buys again, but the farmer usually sells and sells and sells, until he is practically "sold out." Then he "goes West," and with him "Westward the course of Empire takes its way." Is not this the history of the civilized world?

The Application of Mineral Fertilizers.

There is one general rule to be observed in the application of fertilizers; namely, *thoroughly mix them with the soil.* Apply them uniformly and make them a part of the soil itself,—by disking, dragging, plowing, harrowing, cultivating,—any way to get them thoroughly incorporated with the soil. At least one year's time will usually be required to fully produce this effect.

I am often asked if it is a good plan to apply the fertilizer in the hill with corn. This is very poor practice. The effiect of such an application is usually to over stimulate the early growth of the corn, meanwhile the roots do not properly develop and spread through the soil in proportion to the growth above ground, and consequently when the drier season comes on and earing time approaches, the corn fertilized in the hill suffers more than the unfertilized corn and frequently produces a smaller yield of ears at harvest time.

People sometimes ask when is the best time to apply fertilizers. I think almost any time will do well, if it is about a year before you expect marked results. Fertilizers may well be applied whenever you can get on the land and are not too busy with other work. Probably as good a practice as any is to apply them in the fall or spring and then cultivate the land in corn and follow the next year with oats and clover. The effect should be apparent on the clover and it should be marked on a succeeding corn crop.

Heavy applications; that is, from 600 or 800 pounds to one or two tons per acre, may well be applied broadcast as uniformly as possible with a shovel or preferably with a manure spreader, by putting in the box a uniform layer of the material, which may well be applied with the manure. Lighter applications may be made with an end-gate seeder or with a fertilizer drill. For lime or heavy applications of rock phosphate, I would advise using the manure spreader; for bone meal or potash salts, or moderate applications of rock phosphate (300 to 600 pounds), use the end-gate seeder, or fertilizer drill, or even a good force-feed grain drill. In case both phosphorus and potash salt need to be applied to the soil, which is rarely the case, a force-feed grain drill with fertilizer attachment is probably the best implement to use, running the bone meal or rock phosphate through the grain box and the potash salt through the fertilizer box.

On all our soil experiment fields in different sections of Illinois we are using fertilizer disk drills made by the Superior Drill Company, of Springfield, Ohio. This implement not only applies two kinds of fertilizers at once, but it applies each of them at any rate desired and with perfect uniformity; and, at the same time, it cultivates the soil by disking. It enables the farmer to use raw materials instead of ready mixed fertilizers and thus saves the cost of mixing by the fertilizer manufacturer, which usually amounts from $4 to $8 per ton. If only one element of plant food needs to be applied, as is usually the case, the grain box may be used at the same time, (as in sowing wheat or oats), and, of course, grass or clover seed may be sowed through the grass seeder attachment if desired. Somewhat similar implements are manufactured by other companies. The end-gate seeder is also very satisfactory.

Table 3 shows the results of experiments which have been conducted by the Ohio Experiment Station and the Maryland Experiment Station, with several different forms of phosphorus which I believe could profitably be used on some Illinois soils.

The soil experiments carried on during the past twelve years by the Ohio Experiment Station, under the management of Direc-

TABLE 3 (A)—OHIO SOIL EXPERIMENTS.

AVERAGE OF RESULTS FROM WOOSTER AND STRONGSVILLE FIELDS.

(Increase only—bushels per acre.)

Plot No.	Form of phosphorus (with nitrogen and potassium.)	Crop grown.	1st year increase.	2nd year increase	3rd year increase.
26	Bone meal	Corn	2.42	4.16	6.46
29	Slag phosphate	Corn	3.51	9.32	13.19
30	Tankage	Corn	3.89	14.44	10.38
	Average		3.27	9.31	10.01
26	Bone Meal	Oats	6.44	9.45	14.57
29	Slag phosphate	Oats	5.74	7.98	18.67
30	Tankage	Oats	3.71	7.12	10.93
	Average		5.29	8.18	14.73
26	Bone meal	Wheat	1.11	8.24	8.05
29	Slag phosphate	Wheat	2.21	11.32	8.43
30	Tankage	Wheat	.66	9.94	4.69
	Average		1.33	9.84	7.06

(B)—MARYLAND SOIL EXPERIMENTS.

(Increase only,—bushels per acre.)

Plot No.	Form of phosphorus (with legume and potassium)	Increase, corn.			Wheat.
		1895	1896	1897	1899
8	Raw bone meal	1.6	4.4	12.5	13.8
9	Slag phosphate	1.0	3.5	9.0	14.1
11	Ground S. C. rock phosphate	3.0	6.2	11.3	9.1
12	Florida soft rock phosphate	4.6	7.7	13.7	10.1
	Average	1.3	5.5	11.6	11.8

tor C. E. Thorne, are probably the most valuable series of soil investigations by plot experiments which have been conducted in America. In my judgement the value of these experiments to American agriculture is second only to that of the original and now world-renowned investigations of Lawes and Gilbert, which have been in progress during the past sixty years at Rothamsted, England. The Ohio experiments are of especial value to Illinois agriculture, because they have been conducted on soils which in many respects are similar to Illinois soils.

All of the experiments reported in Table 3 show that the full effect of these fertilizers is not produced till the second or third year, and the limit of increase may even then be due to an insufficient supply of nitrogen. In the Ohio experiments a five-year rotation of corn, oats, wheat, clover, and timothy was practiced, and 75 pounds of commercial nitrogen were added; but other experiments in the series (not shown here) prove that still heavier applications of nitrogen further increased the yield, thus indicating that a more liberal use could well have been made of leguminous crops or farm manure. In the Maryland experiments the entire supply of nitrogen, aside from the nitrogen in the soil, was furnished by crimson clover grown in the corn as a "catch" or companion crop; and it is not improbable that the applications of phosphorus would have produced a much larger increase if a more abundant supply of nitrogen had been provided.

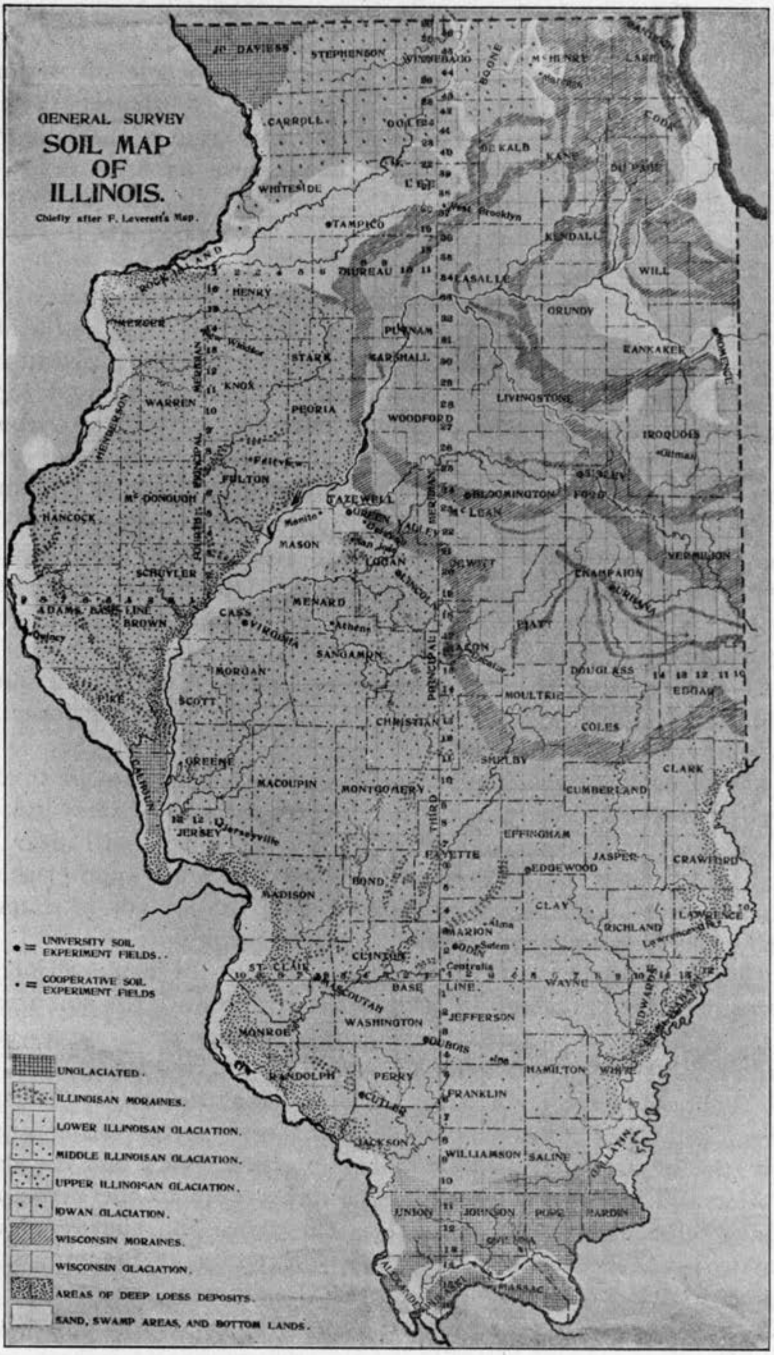
After ten years of investigations, Director Thorne reports that slag phosphate gives better results on Ohio soils than any acidulated phosphate. Untreated rock phosphate was not used in the regular series of Ohio experiments, but it has been used for a shorter time in connection with farm manure, and as stated above its use has increased the value of the farm manure 30 per cent. after paying the total cost of the rock phosphate. It is certainly of much interest to observe that in the Maryland experiments the effect of the untreated rock phosphate from South Carolina and from Florida compared very favorably with that of the slag phosphate. About 500 pounds of ground rock phosphate per acre were applied each year.

All of these experiments strongly indicate that fine ground rock phosphate, as well as bone meal, will be a valuable form of phosphorus for Illinois soils.

We already have soil experiments in progress in Illinois to determine positively the value of the different forms of lime and of phosphorus on different soils in the State, but you will bear in mind that it is only 20 months since the first appropriation was made for investigating the soils of this State and, of course, our results from field experiments are very meager.

Table 4 is believed to show approximately the composition of the principal types of soil in each of the different large soil areas in the State, as shown in the accompanying general survey soil map of Illinois, and briefly described on the following pages.

It should be understood that the divisions shown on the map are not soil types but soil areas, based largely upon the original formation of the soil, and that the composition given and the description and discussion which follow apply only to the principal type of soil found in each area. (In the detail soil survey which has already been begun by the Illinois Experiment Station, with the coöperation of the United States Government, every type of soil, even down to 10-acre fields, is being mapped and analyzed.)


GENERAL SURVEY
SOIL MAP
OF
ILLINOIS.
Chiefly after F. Leverett's Map.
JO DAVIESS
STEPHENSON
WINNEBAGO
BOONE
McHENRY
LAKE
CARROLL
OGLE
DE KALB
KANE
COOK
DU PAGE
WHITESIDE
LEE
KENDALL
WILL
ROCK ISLAND
HENRY
BUREAU
LASALLE
GRUNDY
KANKAKEE
MERCER
STARK
PUTNAM
MARSHALL
KNOX
WARREN
PEORIA
WOODFORD
LIVINGSTONE
IROQUOIS
HENDERSON
FULTON
TAZEWELL
McLEAN
FORD
McDONOUGH
HANCOCK
MASON
LOGAN
DEWITT
VERMILION
SCHUYLER
CHAMPAIGN
ADAMS
BROWN
CASS
MENARD
PIATT
MORGAN
SANGAMON
MACON
SCOTT
DOUGLASS
MOULTRIE
EDGAR
PIKE
CHRISTIAN
COLES
CALHOUN
GREENE
SHELBY
CLARK
MACOUPIN
MONTGOMERY
CUMBERLAND
JERSEY
EFFINGHAM
FAYETTE
JASPER
CRAWFORD
MADISON
BOND
CLAY
LAWRENCE
RICHLAND
CLINTON
MARION
ST. CLAIR
WAYNE
WASHINGTON
JEFFERSON
EDWARDS
WABASH
MONROE
HAMILTON
WHITE
RANDOLPH
PERRY
FRANKLIN
JACKSON
WILLIAMSON
SALINE
GALLATIN
UNION
JOHNSON
POPE
HARDIN
PULASKI
MASSAC
ALEXANDER
FOURTH PRINCIPAL MERIDIAN
THIRD PRINCIPAL MERIDIAN
BASE LINE
● = UNIVERSITY SOIL EXPERIMENT FIELDS.
• = COOPERATIVE SOIL EXPERIMENT FIELDS
UNGLACIATED.
ILLINOISAN MORAINES.
LOWER ILLINOISAN GLACIATION.
MIDDLE ILLINOISAN GLACIATION.
UPPER ILLINOISAN GLACIATION.
IOWAN GLACIATION.
WISCONSIN MORAINES.
WISCONSIN GLACIATION.
AREAS OF DEEP LOESS DEPOSITS.
SAND, SWAMP AREAS, AND BOTTOM LANDS.

Explanation of Map.

According to geological investigation there have been three different times when glaciers, or ice sheets, have covered more or less of the State of Illinois, in consequence of which nearly all of the surface of the State is covered by soils of glacial formation. The first glacier covered all of Illinois as far south as the Ozark Spurs, excepting a part of what is now called Calhoun County and a small area in the northwest corner of the State. The area where the drift, or debris, left from this first glacier still remains the surface is called the Illinoisan Glaciation. For our purpose in soil investigation we divide this Illinoisan Glaciation into three areas, because of the marked difference in the agricultural values and properties of the soil. These three areas we call the lower Illinoisan Glaciation, the Middle Illinoisan Glaciation, and the Upper Illinoisan Glaciation, each of which will be more fully described later.

The second glacier covered only three or four tiers of counties from the north line of the State, but the area did not include the extreme northwest corner of the State. Where the drift from this second glacier is now the surface, it is termed the Iowan Glaciation.

The third and last glacier covered approximately the northeast one-quarter part of the State and this area is called the Wisconsin Glaciation.

According to the formation we have about ten large soil areas in the state, although each of these areas may contain several different types of soil:

1. Unglaciated Area—Chiefly in seven southern counties.
2. Illinoisan Moraines—Chiefly ridges near Kaskaskia river.
3. Lower Illinoisan Glaciation—Chiefly between Wabash and Kaskaskia rivers.
4. Middle Illinoisan Glaciation—Chiefly between Kaskaskia and Illinois rivers.
5. Upper Illinoisan Glaciation—Chiefly between Illinois and Mississippi rivers.
6. Iowan Glaciation--Chiefly in Stephenson, Winnebago, Boone, Carroll and Ogle counties.
7. Wisconsin Moraines—Chiefly broad ridges and rolling prairie in northeast quarter part of the State.
8. Wisconsin Glaciation—Chiefly level prairie in northeast quarter part of the State.
9. Loess Soils—Chiefly narrow strips of upland (5 to 15 miles wide) along Mississippi, Illinois and Wabash rivers.
10. Sand, swamp areas, and bottom lands, scattered over the State.

TABLE 4.—FERTILITY IN ILLINOIS SURFACE SOILS.

Pounds per acre,—tentative data.

No.	Principal type of soil in the area.	Nitrogen (in 7 in.)	Phosphorus (in 7 in.)	Potassium (in 7 in.)	Lime required (in 15 in.)
1	Unglaciated hills..........	1,000	1,000	5,600	900
3	Lower Ill. Gla. prairie.....	2,800	600	4,200	2,400
4	Middle Ill. Gla. prairie....	5,000	1,000	8,400	200
5	Upper Ill. Gla. prairie.....	5,400	1,400	5,600	150
6	Iowan Glaciation prairie...	4,300	1,100	7,400	300
7	Wisconsin Moraine soil...	5,000	1,200	7,400	200
8	Wisconsin Gla. prairie....	6,200	1,600	8,800	00
9	Loess soil, old......	1,800	800	5,600	300
10 (a)	Sand soil	1,100	300	2,400	300
10 (b)	Peaty soil................	67,000	2,000	1,200	600
	Av. U. S. fertile soil.......	5,600	2,000	6,600	00
	German fertile soil........	6,000	2,000	4,000	00
	Ohio soil, Strongsville, O..	4,400	1,400	3,200	(?)

NOTE.—The degree of acidity in the respective subsoils of the above named types of soil is as follows, by number:

Subsoil of No. 1 is strongly acid; No. 3 is very strongly acid; No. 4 is not acid; No. 5 is not acid; No. 6 is moderately acid; No. 7 is not acid; No. 8 not acid and usually contains plenty of lime carbonate; No. 9 is slightly acid; No. 10 (a) is slightly acid; No. 10 (b) is sometimes acid, but usually not acid, and frequently contains much lime carbonate, even in the surface soil.

It should be stated that several of these averages are based upon the analyses of a very few samples of soil (which however are believed to be truly representative of the type.) Consequently these averages should be considered as tentative and subject to revision upon the accumulation of additional data. The data given for the "Average United States fertile soil" are the average of six averages each of which represents as nearly as can be ascertained the average composition of the fertile soils of a state. These six states include Colorado, North Dakota, Minnesota, Michigan, Ohio, and Massachusetts, and the general average here given really represents several hundred separate analyses. These figures are also tentative and subject to revision as more data accumulate regarding the composition of the normal fertile soils of America, but this average is probably the best American standard we now have as to what is, and should be, the composition of a soil which needs no fertilizer of any kind to enable it to produce maximum crops.

The data given for the "German fertile soil" were recently furnished by Professor F. Wohltmann, Director of the Institute for Soil and Plant Investigations, connected with the Agricultural Academy of Bonn-Poppelsdorf, Germany. These numbers represent the standard which Professor Wohltmann has adopted for the composition of a soil which needs no fertilizer of any kind. It is interesting to observe that these two "standards" which were obtained from entirely separate and independent sources are so nearly alike. The amount of phosphorus is exactly the same in each "standard," and it is somewhat surprising that Professor Snyder reported several years ago this same amount for the average phosphorus content of 200 fertile soils of Minnesota.

Probably we cannot do better at the present time than to adopt the German standard and consider that a normal fertile soil should contain 6,000 pounds of nitrogen, 2,000 pounds of phosphorus, and 4,000 pounds of potassium per acre, in the surface soil to a depth of 7 inches. And certainly no lime should be required to a depth of 15 inches.

In adopting this standard we must also assume that the soil is in good physical condition and that it is normal in other respects; namely, that with increasing depth, the nitrogen decreases rapidly, the phosphorus decreases slowly, and the potassium and lime slowly increase in amount, which are the actual conditions in nearly all normal soils. Furthermore, we should bear in mind, this "standard" applies more particularly to grasses and cereal grain crops. For legumes the soil need not furnish any nitrogen, if it is properly provided with phosphorus, potassium, lime, and suitable bacteria. On the other hand, for potatoes, root crops, fleshy fruits, etc., the potassium content should probably be much higher than that given in the "standard."

There are two methods by which we can obtain some idea of the possible productive capacity of soils from a knowledge of their composition: First, by estimating the amounts of plant food which are likely to become available to the crops each year and comparing these amounts with the amounts actually required for the production of crops. Second, by comparing the soil with some standard, or normal, fertile soil.

(1). By the first method we may assume, for example, that about one per cent. of the total stock of phosphorus and potassium and two per cent. of the nitrogen contained in the surface soil may become available for the use of plants each year. By pointing off two decimal places in Table 4, and multiplying the nitrogen by two, we then have the numbers which represent these percentages of plant food in the soils (See Table 5). If this assumption were correct then the black prairie soil of the Wisconsin Glaciation would give up 16 pounds of phosphorus, or as much as is contained in 94 bushels of corn ; while the white clay soil of the Lower Illinoisan Glaciation would give up 6 pounds of phosphorus, or enough for 35 bushels of corn. Of course, this is at best only an approximation, but nevertheless it serves to illustrate with some degree of accuracy an absolute fact; namely, that, at the most, it is only a small percentage of the total stock of fertility that becomes available to crops during any one season. This percentage will certainly vary somewhat with the season and it will vary with different elements and with different soils, but it is altogether likely that the richer soils will yield a larger percentage of their large stock than the poorer soils will of their small stock. In other words, the soil of the Wisconsin Glaciation, instead of 16 pounds of phosphorus, may give up 18 or 20 pounds, while the soil of the Lower Illinoisan Glaciation instead of 6 pounds may give up only 4 or 5 pounds of phosphorus.

TABLE 5. APPROXIMATE ANNUALLY AVAILABLE FERTILITY IN ILLINOIS SURFACE SOILS,—ROUGHLY ESTIMATED.

Pounds per acre.

Principal type of soil in the area.	Nitrogen (in 7 in,	Phosphorus (in 7 in.)	Potassium (in 7 in.)
Unglaciated hills	20	10	56
Lower Illinoisan Glaciation prairie	56	6	42
Middle Illinoisan Glaciation prairie	100	10	84
Upper Illinoisan Glaciation prairie	108	14	56
Iowan Glaciation prairie	86	11	74
Wisconsin Moraine soil	100	12	74
Wisconsin Glaciation prairie	124	16	88
Loess soil, old	36	8	56
Sand soil	22	3	24
Peaty soil	1340*	20	12
Av. U. S. fertile soil	112	20	66
German fertile soil	120	20	40
Ohio soil, Strongsville, O.	88	14	32
Contained in 100 bu. of corn	**100**	**17**	**19**

*Peaty soils decompose very slowly, consequently a very much smaller amount of nitrogen would become available than is here indicated.

In trying to study and to understand the subject of soil fertility and the meaning of soil analyses, it is exceedingly useful and helpful to fix in mind the fact that only a small percentage of the total stock of fertility contained in the soil ever becomes available to plants during any one season. As a general average, 1 per cent. is perhaps approximately correct for phosphorus and potassium; while probably 2 per cent. is more nearly correct for nitrogen.

Of course, we should bear in mind that there is plant food in the subsoil, but its percentage of availability is very much lower than that of the plowed soil, and in many cases, especially with shallow rooting annual plants and cultivated crops, this additional supply of plant food is doubtless fully counterbalanced by losses of plant food in drainage and surface washing.

(2). By comparing the composition of the different soils of Illinois with that of the standard fertile soils it appears that the peaty swamp soils are the only soils of the State which do not need to grow leguminous crops to maintain their supply of nitrogen, and many of the soils are markedly deficient in nitrogen. As a rule, the soils which most need to grow legumes are markedly acid and must be given an application of lime before legumes can be expected to be very successful upon them.

Perhaps the most striking fact is that none of the soils are very rich in phosphorus, while many of them are considerably below the standard fertile soil, and two or three soils of large area are markedly deficient in that element, particularly the large area of so-called white clay soil of the Lower Illinoisan Glaciation.

With the exception of the peaty swamp soil and the sand soil, all of the soils of the State are above the German standard in potassium, although the soil of the Lower Illinoisan Glaciation is but little above it and is not equal to the American average. It seems not improbable that applications of potassium might prove profitable on this soil, especially for growing such crops as apples, potatoes, sugar beets, or other crops which require large amounts of potassium; indeed, we have some evidence which strongly indicates that potassium may be profitably used even on the Wisconsin moraine soil when such crops are frequently or continuously grown on the same field.

Table 6 shows the results which have been obtained from the application of different elements of plant food to an Ohio soil whose composition is shown in Table 4.

The composition of this Ohio soil (see Table 4) shows that it is as well supplied with phosphorus as any of the Illinois soils excepting the Wisconsin Glaciation prairie and the peaty soil, while it is poorer in both nitrogen and potassium than most Illinois soils.

The results of ten years' experiments show that phosphorus has been used on this Ohio soil with very large profit while nitrogen and potassium have been applied at a marked financial loss in nearly every instance. As most of the Illinois soils are better supplied with nitrogen and potassium than the Ohio soil it seems very sure that these elements should not be purchased for use on ordinary Illinois prairie soils, unless it may be that potassium could be used with some profit for special crops such as referred to above; and, possibly, even for other crops on the Lower Illinoisan Glaciation (see Table 8). In one instance potassium was found to yield some profit when used for potatoes on the Ohio soil.

On the other hand, if applications of phosphorus are profitable on the Ohio soil, it would seem certain that they would be even more profitable on many Illinois soils, especially those which are markedly deficient in phosphorus but which are well stocked with potassium and either do have or could have abundant supplies of nitrogen if proper use were made of lime and legumes, or farm manure.

TABLE 6. SOIL EXPERIMENTS AT STRONGSVILLE, OHIO.
(Average of ten years)
(L—lime: N—nitrogen: P—phosphorus: K—potassium)

Plot No.	Plant food appl'd	Cost of fertilizer in 5 years. N	P	K	Total.	Value of increase.	Net profit.	Net loss.
5	N	$11.25	$	$	$11.25	$ .93	$	10.32
2	P		2.40		2.40	12.54	10.14	
3	K			6.60	6.60	.45		6.15
6	NP	11.25	2.40		13.65	16.76	3.11	
9	NK	11.25		6.60	17.85	3.23		14.62
8	PK		2.40	6.60	9.00	12.13	3.13	
11	NPK	11.25	2.40	6.60	20.25	19.09		1.16
29*	LNPK	11.25	2.40	6.60	20.25	21.56	1.31	

Cost per pound.		Actual value of elements per pound.				
Element.	Cost.	Alone.	After N.	After P.	After K.	After 2 others.
Nitrogen.......	15c	1.2c	c	5.6c	3.7c	9.1c
Phosphorus....	12	62.7	79.2	....	58.4	79.3
Potassium	6	.4	2.1	.4	....	2.1
P in 29*.......	12					91.7

*In plot 29 the phosphorus was applied as slag phosphate and its higher value on this plot is undoubtedly due to the lime contained in the slag.

Table 7 gives some results from pot culture and field experiments which show (a) the value of nitrogen first, and then of phosphorus, on the old unglaciated hill soil of southern Illinois, Pulaski County, (see Plate 2); also (b) the value of phosphorus first, then of nitrogen, and then of potassium on the Lower Illinoisan Glaciation, Marion County, (see Plate 3); and, lastly, (c) the marked value of potassium on the peaty swamp soil, Whiteside County, (see Plate 4). By reference to Tables 4 and 5 it will be seen that these results are in accordance with what might be expected from the composition of these soils. (As a matter of fact, the nitrogen content of the unglaciated hill soil which was actually used in these experiments was lower than the average for that soil which is shown in Table 4, while the phosphorus in the soil used was above the average.)

TABLE 7.—CROP YIELDS IN SOIL EXPERIMENTS.

Soil test No.	Kind of plant food applied.	(a) Unglaciated hill soil (N most needed).	(b) Lower Illinoisan glaciation (P most needed).	(c) Peaty swamp soil, Whiteside County (K most needed).	
		Wheat, grams.	Wheat, grams.	Ear corn, bushels.	Fodder, pounds.
1	0	3.0	11.0	0	1,000
2	L	3.9	11.6	0	800
3	LN	26.0	9.2	0	1,200
4	LP	3.3	13.6	0	2,000
5	LK	3.3	10.3	36.3	3,600
6	LNP	34.0	20.6	0	1,400
7	LNK	32.8	7.2	40.0	3,500
8	LPK	2.1	13.7	37.5	3,100
9	LNPK	34.4	26.5	60.0	4,400
10	NPK	30.6	24.5	52.5	4,750
11	0	3.0	9.9		
12	0	3.4	9.5		

(a) Compare 8 and 9 for maximum effect of nitrogen.
(b) Compare 7 and 9 for maximum effect of phosphorus.
(c) Compare 6 and 9 for maximum effect of potassium.

Table 8 shows (a) that in field experiments on the soil of the Lower Illinoisan Glaciation (Perry County) phosphorus increased the yield of wheat from 13.1 to 16.5 bushels per acre, while the addition of potassium further increased the yield to 20.3 bushels; (b) that on the soil of the Middle Illinoisian Glaciation (St. Clair County) phosphorus increased the yield of wheat from 17.1 to 26.4 bushels, while with potassium added to the phosphorus the yield was still further increased to 33.8 bushels, as the average of three

PLATE 2.—Wheat on Unglaciated Soil (Pulaski County Hills) Effect of Nitrogen.

PLATE 3.—Wheat on Lower Illinoisan Glaciation Soil (Marion County Prairies) Effect of Phosphorus.

PLATE 4.—Corn on Swamp Soil (Whiteside County "Poison" Land) Effect of Potassium.

quite discordant results; and (c) that on the Wisconsin moraine Soil on the Experiment Station farm at Urbana (Champaign County) applications of lime, of both lime and phosphorus, and of lime, phosphorus, and potassium, altogether, produced very beneficial and profitable results. The phosphorus was applied in the form of bone meal at the rate of 320 pounds per acre. Potassium chlorid was applied at the rate of about 160 pounds per acre (a double application of potash salt was given to the sugar beets on plots 8, 9, and 10). It should be stated that two crops of sugar beets had been produced on this field previous to 1892. No fertilizers had ever been applied to any of these plots before the fall of 1901. The average of three years' previous corn crops, is given in the last column and shows that these plots were exceedingly uniform in their productive capacity previous to the application of fertilizers for the 1902 crop.

TABLE 8. CROP YIELDS IN SOIL EXPERIMENTS.

Soil test No.	Kind of plant food applied for 1902.	(a) Lower Illinoisan glaciation.	(b) Middle Illinoisan glaciation.	(c) Wisconsin moraine.	
		Wheat, bushels, 1902.	Wheat, bushels, 1902.	Sugar beets, tons, 1902.	Corn, bu., average of 3 years.
1	0	12.8	19.7	9.23	66.8
2	0	12.4	15.2	7.80	67.0
3	0	12.4	15.3	9.53	66.3
	Average	12.5	16.7	8.85	66.7
4	L	13.3	17.7	13.14	71.8
5	L	12.9	16.5	14.52	71.7
	Average	13.1	17.1	13.83	71.8
6	LP	16.9	24.7	17.21	68.0
7	LP	16.1	28.0	18.22	67.4
	Average	16.5	26.4	17.72	67.7
8	LPK	20.8	29.8	21.83	68.7
9	LPK	19.4	31.7	24.08	67.4
10	LPK	20.8	39.8	23.86	64.7
	Average	20.3	33.8	23.25	66.9

NOTE.—These experiments will ultimately include the growing of leguminous catch crops (on plots 2, 4, 6, and 8), and the application of farm manure about once in four years (on plots 3, 5, 7, and 9) and the effect of this additional treatment will be ascertained from subsequent crop yields.

(b) The particular soil used for this series of experiments was found to contain much less potassium than is contained in the average soil of this type; that is, the Middle Illinoisan Glaciation prairie.

The sugar beets were worth about $4.60 a ton and the total cost of the fertilizers on plots 8, 9, and 10 was about $12 per acre. Of course, legumes and manure are to be used on some of these plots in connection with the use of the mineral elements of plant food and probably we shall have more marked results after one or two crop rotations.

Lime is not expected to be of much direct benefit to wheat, but it should benefit legumes.

Tentative Recommendations and Suggestions for Different Types of Soil, Representing Large areas of Illinois Lands.

The following kinds of treatment recommended, or suggested for trial, for the soils of Illinois, are, as a rule, to be considered in addition to the use of the manure produced on the farm. I certainly ask for some measure of charity from Illinois farmers in their consideraion of the recommendations which are here made for maintaining and increasing the productive capacity of Illinois soils. I am sure you will appreciate the fact that to investigate the soils of a state like Illinois is a task of no small magnitude. Bear in mind, for example, that the northern boundary of Illinois almost coincides with the southern boundary of Vermont and New Hampshire, while the southern point of Illinois is only 30 miles north of the southern boundary of Virginia. Boston, Massachusetts, and Richmond, Virginia, both fall within the latitude of the State of Illinois. This range of latitude includes Massachusetts, Connecticut, New Jersey, Delaware, Maryland and Virginia.

You will also bear in mind that less than two years have elapsed since these investigations began. We certainly realize that, as yet, our information is meager; our results are few; and the conclusions drawn are tentative. They apply more strongly to old worn soils than to new lands. These recommendations and suggestions are made with the hope that they may be given careful trials at least on a few acres of land and for at least five years, and the results compared with control or check plots which are treated in the ordinary way. In making these trials, don't try to compare clover with lime, but compare clover with lime *and* clover both together; and don't compare manure with bone meal, but compare manure with manure *and* bone meal both together. For use in traveling you would not compare a horse with a carriage, but you would compare a horse with a horse *and* carriage.

While the recommendations as to treatment are very general, it is believed that when supplemented by good sense and general knowledge, more than one-half the farmers of Illinois can get some ideas or suggestions which they will be able to see are applicable to the actual soils they are cultivating. Nearly every farmer recognizes different types of soil, and, as a rule, farmers know which is the principal or commonest type of soil in their section of the State, whether they live in Johnson, Clay, Sangamon, Warren, Stephenson, McHenry, or Douglas county, or in any other county in any of the large soil areas of the State.

All of the recommendations are meant only to supplement good farm practice. Always make use of farm manures, grow clover or other legumes, prepare the ground well, plant good seed, and practice good cultivation ; but in addition to all of this, try the effect of applying lime, phosphorus, or potassium, in accordance with the composition of your type soil and the needs of the crop (See Table 1). Where a liberal use of leguminous crops is recommended, sow cow peas or soy beans or vetch in the corn at the last cultivation ; sow clover or vetch in the oats and wheat or sow cow peas, soy beans, or vetch as soon as possible after the oats and wheat are harvested. In addition to this a full crop of legumes should be grown once in about 3 to 5 years.

1. Unglaciated Soil.

Principal type: Red clay hill soil, common in the following counties: Union, Johnson, Pope, Hardin, Alexander, Pulaski and Massac.

Treatment recommended: 1,500 to 2,000 pounds of limestone per acre and a liberal use of leguminous crops as catch and cover crops and in rotations. Additional treatment suggested for trial; 200 pounds bone meal (or 500 pounds rock phosphate*) per annum.

2. Illinoisan Moraines.

(Not yet investigated.)

3. Lower Illinoisan Glaciation.

Principal type: "White clay," prairie soil, common in the following counties: Fayette, Effingham, Jasper, Marion, Clay, Richland, Washington, Jefferson, Wayne, Perry, Franklin, Hamilton, and to some extent in nearly all adjoining counties.

Treatment recommended: 1 to 2 tons limestone per acre and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of leguminous crops as catch and cover crops and

*Until we have more definite information on the subject, rock phosphate should not be substituted for bone meal, excepting, perhaps, on soils rich in organic matter, or in connection with a liberal use of leguminous green fertilizers or farm manure, or both.

in rotations. Additional treatment suggested for trial: 100 to 200 pounds potassium chlorid or potassium sulfate especially for potatoes, root crops, and orchards.

4. Middle Illinoisan Glaciation.

Principal type: Brown prairie soil, common in the following counties: Cass, Menard, Logan, Scott, Morgan, Sangamon, Greene and in parts of Macoupin, Jersey, St. Clair, Clinton, Bond, Montgomery, Christian and Macon.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes.

5. Upper Illinoisan Glaciation.

Principal type: Dark brown prairie soil, common in the following counties: Mercer, Henry, Stark, Warren, Knox, Peoria, Hancock, McDonough, Fulton, Schuyler, and in parts of Adams, Brown, and Pike.

Treatment recommended: Liberal use of leguminous crops. Additional treatment suggested for trial: 500 pounds limestone and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum.

6. Iowan Glaciation.

Principal type: Brown rolling prairie soil, common in the following counties: Stephenson, Winnebago, Carroll, Ogle, and in parts of adjoining counties.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes, as catch and cover crops and in rotations.

7. Wisconsin Moraines.

Principal type: Dark brown rolling prairie soil, common in the following counties: McHenry, Lake, DeKalb, Kane, Cook, DuPage, Will, Kendall, LaSalle, Livingston, Ford, and in parts of Bureau, Marshall, Tazewell, McLean, Dewitt, Champaign, Vermilion, Macon, Shelby, Coles and Edgar.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes, as catch and cover crops and in rotations.

8. Wisconsin Glaciation Prairie.

Principal type: Black level prairie soil, common in the following counties: DeKalb, Kane, Bureau, LaSalle, Kendall, Grundy, Will, Kankakee, Putnam, Marshall, Woodford, Livingston, Iroquois, Tazewell, McLean, DeWitt, Piatt, Champaign, Vermilion, Macon, Moultrie, Douglas, Coles, Edgar, and in parts of Ford, DuPage, Cook, and Lake.

Treatment recommended: Legumes in crop rotation. Additional treatment suggested for trial: 200 pounds bone meal (or 500 pounds rock phosphate) per annum, and also, on old worn soil, or slightly rolling land, 500 pounds limestone per acre.

9. Loess Soil.

Principal type: Light brown rolling upland soil, containing some very fine sand, common along the Mississippi, Illinois, and Wabash rivers, usually occupying a strip of upland 5 to 10 miles wide.

Treatment recommended: 500 pounds limestone per acre, and then 200 pounds bone meal (or 500 pounds rock phosphate) per annum and a liberal use of legumes as catch and cover crops and in crop rotations.

10. (a) Sand Soils.

Common in parts of Whiteside, Lee, Henry, Tazewell, and Mason counties and in some bottom lands along Mississippi river.

Treatment recommended: 200 pounds bone meal (or 500 pounds rock phosphate) per annum and liberal use of barn yard manure. Additional treatment suggested for trial: 500 pounds of limestone per acre, and then 100 pounds potassium chlorid per annum and a liberal use of legumes.

10. (b) Peaty Swamp Soils.

Common in parts of McHenry, Kane, Whiteside, Lee, Henry, Bureau, Kankakee, Tazewell, Mason, and to some extent in many other northern counties.

Treatment suggested for trial: 50 to 100 pounds potassium chlorid per acre per annum, with light dressings of farm manure if found beneficial.

In conclusion I would say that nothing else,—most emphatically nothing else,—pertaining to the business of farming compares in importance with the subject of soil fertility, and yet there is probably no subject about which Illinois farmers have been more indifferent in the past. I believe in well bred and well fed stock;

I believe in making, saving, and using farm manures; I believe in good cultivation; I believe in growing the best varieties of crops; I believe in the improvement of crops,—in the improvement of corn by breeding; I believe in increasing the protein content of corn; but I know that you cannot make protein without nitrogen; I know that you cannot get nitrogen economically without legumes and bacteria; I know that you cannot grow legumes successfully on acid soils; and I know that a soil which gives up only 5 pounds of phosphorus per annum cannot yield 100 bushels of corn.

Last season we planted some improved seed corn on good soil at the University and it yielded 90 bushels per acre; we planted exactly the same kind of corn on the white clay soil of the Lower Illinoisan Glaciation and it yielded less than 15 bushels per acre. This is not a difference in the variety; it is a difference in the fertility of the soil.

On the other hand, we have obtained some striking indications of the value of plant food for making crops. For example, where we applied $8 worth of plant food in St. Clair county, we got an increase of 16 bushels of wheat the first year; where we applied $12 worth of plant food on the University farm, we got an increase of 14 tons of sugar beets which were worth more than $60 for factory use, and which we sold for $42 for feed; where we applied $4 worth of plant food to the peaty swamp soil of Whiteside county, we got 36 bushels of corn for it the first year. Some ot these results are striking and they may be extremes, and yet in no case have we reason to doubt their reliability. (The tabular statements show all of the variations in duplicate and triplicate results.) The experiments are conducted with the sole desire to learn the truth, to obtain results which may be obtained on any scale by any Illinois farmer who may try to practice what the experiments preach. These experiments must be continued; the results must be verified or proven incorrect. It should be borne in mind, however, that our experiments include the use of legumes for increasing the nitrogen in the soil and that we have not yet had sufficient time to determine the effect of leguminous crops upon succeeding grain crops both with and without the addition of the other elements of plant food and with applications of manure, the above results having been obtained with the use of the mineral elements only.

One thing, however, we believe is settled; namely, that we have discovered, proven, and demonstrated, for all time, that alfalfa can be grown successfully on Illinois soil; that is, on soils which are not acid, which are not deficient in phosphorus, and which are

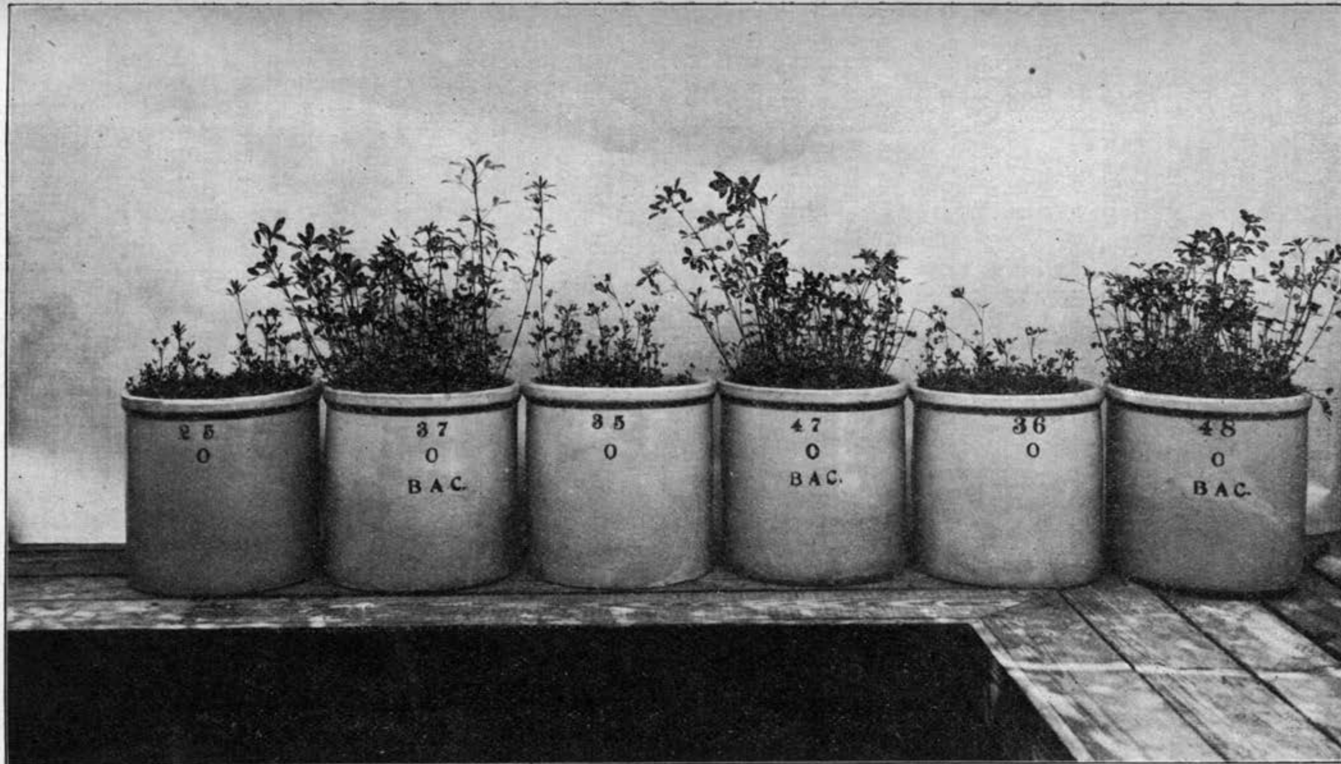


PLATE 5.—Alfalfa on Wisconsin Moraine Soil (Champaign County Rolling Prairie) Effect of Bacteria only.

inoculated or infected with the alfalfa bacteria (See Plate 5 and also Bulletin No. 76, "Alfalfa on Illinois Soil."), and these results are not considered as tentative ; they are conclusive. There is no longer a question as to whether alfalfa can be grown in Illinois. The only question is, will you provide the proper conditions for it? On our own field at the University (on Wisconsin moraine soil) less than $1 worth of lime made more than $10 increase per acre in the alfalfa hay, and $4 worth of phosphorus made an additional increase of $15 worth of hay, while the presence or absence of the alfalfa bacteria made the crop a success or a failure, respectively. Alfalfa is not grown at the University alone, but it is now growing successfully (on well infected soils free from acidity) in many different places in the State, and yielding from 6 to 10 tons per acre annually.

Regarding many things pertaining to Illinois soils I do not have absolute knowledge or sufficient results to justify fixed opinions, but I do have a tentative opinion that the possibilities of financial profit to be derived from the purchase of lime and phosphorus and their application and use in connection with leguminous crops and farm manures on very large areas of Illinois soils are not yet dreamed of by the owners of Illinois lands. There are cultivated soils in the State which contain in the plowed soil only $5 worth of phosphorus per acre, and the subsoil is no richer. That the productive capacity of these soils is limited by their low phosphorus content, is beyond question ; that it could be doubled by doubling the phosphorus content, though not yet fully demonstrated, seems highly probable. That the average yield of corn on Illinois soils can be profitably increased from 37 bushels to 75 bushels per acre seems entirely possible. But what is needed ? First, the careful use of farm manure, and, in addition to that, perhaps a ton or two of lime or limestone once in ten years, a generous use of phos phorus at a cost of a few cents per bushel of corn, and, ultimately, it may be, a cent or two more per bushel of corn for potassium, and then a liberal use of the element nitrogen which everywhere rests upon the surface of the earth in inexhaustible quantities. However well this may sound in theory and however feasible it way appear to be, we must bear in mind that it has not been fully proven or demonstrated ; but if we can prove and demonstrate that the fertility of Illinois soil can be profitably increased and permanently maintained, then we shall accomplish a work the value of which almost passes computation and comprehension. And when I say "we," I mean every man who has assisted or is assisting in this great work. I mean Andrew S. Draper, the president of the University of Illinois whose intellect perceived the fact that "The wealth of Illinois is in her soil and her strength lies in its intelligent development." I mean Eugene Davenport, Dean of the College of Agriculture and Director of the Experiment Station, whose mind conceived the tremenduous importance to Illinois Agriculture of the investigation and the preservation of Illinois soil, and to whom more than to any other one man credit is due that such investigations are now in progress ; I mean the Illinois Farmers' Institute, the organization which now stands as a guardian over the soils of this State, and whose members asked for, and secured the initial appropriation for soil investigations ; I mean the members of the Advisory Committee who serve the State without pay and give practical and valuable advice regarding these lines of work ; I mean the progressive farmers with whom we are cooperating in different sections of the State, whose public spirit and whose patience and watchful care over experiments on their farms and whose kindly treatment of myself and my associates make the work a pleasure to us, and of greater value to the State ; and last, but not least, I mean L. H. Smith and J. H. Pettit, J. G. Mosier and E. M. East, W. F. Pate and J. E. Readhimer, the trained and skilled analysts and the accurate field assistants who work long hours in the laboratories and in the fields and upon whose work depends the accuracy of every conclusion drawn regarding the fertility of Illinois soils and the effects of soil treatment.

But I must add one more word : If we do prove conclusively that the fertility of all of the soils of Illinois cannot be maintained by the use of legumes and the manure made from Illinois crops alone, and if we do demonstrate absolutely that the purchase of any element of plant food is necessary and profitable, then, whoever buys plant food for use on Illinois soil, let him not buy a tonic or a stimulant or a trivial amount of some highly manufactured and high priced so-called commercial fertilizer which shall only urge the soil to greater exhaustion and result in no permanent good, but let him buy liberal amounts of the real elements as near to the raw materials as possible such as fine ground limestone from the immense natural deposits of our own state, and pure phosphates such as bone meal (originally a farm product) or as fine ground rock phosphate from the very extensive phosphate mines of the southern states, and, if necessary, potassium from the abundant supplies of the German potash mines; and then let him apply at least two pounds for every pound he removes in crops ; let the supply increase and not decrease ; let the soils of Illinois not grow poorer but richer and richer,—for the land's sake, for your children's sake, and for Illinois' sake.

If we do learn that this is possible, then let us have one country on earth—let us have one state in this Union, whose soils shall not be ruined and whose children shall not be left with only a memory or a tradition of the bountiful harvests of former years.

Listen: One and one-half million tons of rock phosphate is the annual production of the mines of the United States.

Listen: One million tons of this material (two-thirds of the total product) is the annual export to foreign countries.

Americans are proud today that our exports exceed the imports. Are we proud of this export trade? If there is any one factor more potent than others to finally ruin the agriculture of this state,—to reduce all our lands to the level of the worn out lands of the Eastern States and of the countries of Europe, *many of which cannot today produce their own supply of bread*,—I say if there is any one thing which shall ultimately bring this condition upon us or upon our children, I believe it is the loss of phosphorus.

I am neither sensational nor merely theoretical. If anything I am practical. Pardon me for the personal remark. The greater part of my life I have been a practical farmer,—not a "side walk" farmer, but just a plain every day farmer in plain blue overalls,—with hands which are still calloused from years of farm work.

Farm work! If working in the field from sunrise till sunset,—plowing, sowing, planting, cultivating, harvesting, stacking, threshing,—if this and the milking of 10 or 12 cows twice a day besides other "chores," is farm work, then I have done farm work,—not merely for a month or a season, but for years.

I do not speak of this boastingly. I speak of it because I want your confidence and the confidence of the Illinois farmers whom you represent. And I want your help and cooperation in trying to make of Illinois farming something more than farm work. There was nothing in my farm work to be especially proud of, except, possibly, my willingness to work. I did the work as my father and my father's father had done it. I worked hard but I worked ignorantly.

I well remember that I worked just as hard and took as much pains to get a crop of 15 bushels of wheat from *our* land as Charles Cass, a neighbor only three miles from us, did to raise 30 bushels on some of his land. Why was the difference? We said he had better land. But why his land was better I did not know. I did not know that plant growth is absolutely dependent upon the presence of certain elements of plant food in the soil. I did not know that when the available supply of any one of these essential elements falls short then the crop must also inevitably fall short, no matter how hard I worked. As a matter of fact I knew no more about the land than Lot knew four thousand years ago when he parted from Abraham and chose to dwell "in the land of the plain of Jordan." Certainly I knew how to do farm work; I was well trained in most all farm operations, from digging out grubs and stumps in the timber land, or breaking the prairie sod with a four horse team, to building a barn or granary, or stacking wheat or oats to shed rain.

Nitrogen! phosphorus! potassium! available fertility! nitrifying and nitrogen-gathering bacteria! fixation of carbon! soil acidity!—Have those words anything to do with farming? If so, I did not know it. It seems to me that all I knew about farming was to work myself and to "rest" the land by rotating crops. And we rotated crops just as an Illinois farmer told me last summer he does. I asked him what crop he usually grew after wheat. He said, "That depends. If we get a fairly good crop of wheat, we usually grow wheat again." So did we. We grew wheat till the land grew tired, then we gave it a "rest" by growing corn or oats or timothy. Why clover would not grow we did not know.

But this I do know, that when my good father started me to an agricultural college he said, "Try to learn something about the soil;" and I know that when I began to study chemistry I said to my teacher, "Let me learn to analyze soils," and I fail to remember any more bitter disappointment than I had then when the professor said, "That is a hard thing to do; for to analyze the soil is one of the most difficult chemical analyses to make, and, furthermore, soil analysis doesn't seem to mean very much."

Nevertheless, I have learned to analyze soils, and to me soil analysis *means very much*.

Again I beg your pardon for these personal remarks.

But let me ask you, why are the people of Europe buying 1,000,000 tons of American rock phosphate each year? Are they ignorant and mistaken regarding its value; and is all the wisdom pertaining to agricultural science and practice locked up in the minds of the good, hardworking, honest men who run many of the farms of Illinois for $5 an acre cash rent or for one-half of all they can squeeze out of the soil?

Gentlemen of the Illinois State Farmers' Institute, my knowledge is small and my data few, but my opinion is that every ton of bone meal and every ton of rock phosphate annually produced in the United States could be used with marked profit upon the soils of Illinois, Indiana, and Ohio. I said with profit; but I also say, were there no marked profit in it, we should put back upon the soil at least as much phosphcrus as we take off,—Yes we should put back as much as we have taken off during the past half century or more. But I believe that the purchase and intelligent use of phosphorus on many Iiiinois soils will ultimately pay a higher interest on the investment than the purchase of Illinois soils themselves, at present prices. When you buy land you do not expect it to pay back the principal the first year, neither should you expect it from heavy applications of plant food of which perhaps 90 per cent. remains in the soil to benefit succeeding crops.

I do not advise farmers to rush into the purchase of phosphorus or other plant food on a large scale, but I do advise every land owner to lay off two uniform strips of land, about one acre each, through every important field, to take the exact yields of those two strips for a year or two, then to apply to one of these strips from year to year the treatment which from all the information obtainable he thinks ought to be given to it to insure the permanent maintenance or increase of its productive capacity; and then, if he finds it is profitable, or even if he can barely afford to do it, I advise him to apply this treatment to his whole farm, excepting only the untreated acre, which should always be reserved as a check to show what the soil would do without such treatment.

The Illinois State Farmers' Inststute is the organization which first asked for an appropriation for the investigation of the soils of the State, and I trust the future generations will give you honor for it.

I now assume that the members of the Illinois State Farmers' Institute will be the leaders in applying and extending the knowledge which may be derived from these investigations, as rapidly as results may be secured and verified which shall be found practical for preserving the productive capacity of Illinois soils.

As I said in the beginning:

If the greatest study of mankind is Man, the next greatest study is the soil; for, upon the soil, depends the preservation of Man.

If it is true that American agriculture is the fundamental support of the American Nation, it is equally true that soil fertility is the absolute support of American Agriculture.

If he who makes two blades of grass grow where but one grew before is a public benefactor, then he who reduces the fertility of the soil so that but one ear of corn grows where two grew before is a public curse.